

VACLAV HOUSA, ERVIN SCHEIBNER, ZDENĚK STRÁNÍK<sup>1</sup>

## TITHONIAN STRATIGRAPHY OF WEST CARPATHIANS

### STRATIGRAFIA TITÓNU ZÁPADNÝCH KARPÁT

**Abstract.** Review of the present knowledge of the Tithonian stratigraphy in West Carpathians on the basis of modern paleontological, sedimentary-petrographical, geological and lithological investigations (Table 1: distribution of Calpionella, Table 2-3: review of the Tithonian stratigraphy in West Carpathians).

Sedimentation took place in almost whole the Tithonian sedimentary district of West Carpathians. By D. Andrusov (1959) we may distinguish on the basis of sedimentary development of the Dogger and Malm these geosynclinal and geanticlinal zones (from the north, respectively north-west to south):

1. Elevated zone of Pavlovské kopce and Štramberg,
2. Geosynclinal zone of Cetechovice,
3. Geanticlinal zone of Czorsztyn,
4. Geosynclinal zone of Pieniny,
5. Geanticlinal zone of Tatrids,
6. Geosynclinal zone of Veporids and Gemerids.

Within these zones it is possible to distinguish series of the geosynclinal and geanticlinal zones of lower category. On the whole, geanticlinal zones are characterized by more shallow-water developments than geosynclinal ones. In some geanticlinal zones sedimentation was interrupted or shallowed due to the young-Cimmerian movements.

#### *1. Elevated zone of Pavlovské kopce and Štramberg*

(Elaborated by Z. Stráník and V. Houša)

On the territory of Czechoslovak socialist republic we consider as belonging to this zone occurrences of the Tithonian limestones found in Pavlovské kopce and the vicinity of Štramberg and also the lower Těšín slates.

Gradual transgression of sea from the Carpathian sedimentary district into that of the Štramberg was at the beginning of the Upper (? Middle) Tithonian, into the sedimentary district of Pavlovské kopce already much earlier (probably in the Oxfordian). In the Štramberg district arose a reef-sedimentation of the Štramberg limestones, in that of Pavlovské kopce deposited the Klentnice

<sup>1</sup> Prom. geol. V. Houša, Geological Institute of Czechoslovak Academy of Sciences, Spálená 49, Prague II. Prom. geol. E. Scheibner, Department of Geology of the Faculty of Natural Sciences of J. A. Comenius University, Gottwald's sq. 2, Bratislava. Prom. geol. Z. Stráník, Central Geological Institute, Hradební 9, Prague 1.

beds which grade upwards into the Ernstbrunn limestones (a stratigraphical equivalent of the Štramberk limestone). This reef-sedimentation was due to the elevation at the south-eastern margin of Bohemian massif. In the depression of Bachowice deposited in the Tithonian the lower Těšín slates (M. Książkiewicz, 1956; Z. Roth, 1962).

Table 1.

TITHONIAN			NEOCOMIAN			
Lower	Middle	Upper	Tithonian	Valanginian	Hauterivian	Berremian
						<i>Calpionella alpina</i> Lorenz
						<i>Calpionella elliptica</i> Ladisch
						<i>Calpionella intermedia</i> Delga
						<i>Calpionella unduloides</i> Colom
						<i>Stirruposella carpathica</i> (Murg. & Hlg.)
						<i>Stirruposella oblonga</i> (Ladisch)
						<i>Calpionellites Jordan</i> (Colom)
						<i>Stirruposella gadischiana</i> Colom
						<i>Calpionellopsis thalmani</i> (Colom)
						<i>Calpionellopsis simplex</i> (Colom)
						<i>Calpionellites neocomiensis</i> Colom
						<i>Stirruposella longa</i> (Colom)

THE EXTENSIONS OF CALPIONELLES IN THE KLIP-PEN BELT IN SLOVAKIA (E. SCHEIBNER, 1962)

Zone of Pavlovské kopce represented the southern part of the geanticlinal zone of Pavlovské kopce—Štramberk. It emerges south of the river Dyje in front of the Ždánice nappe and in the south it continues in fragments into the zone of Waschberg in Austria. During the Jurassic this region separated the geosynclinal sedimentary district from the epicontinental sedimentary district. Marine sedimentation in this zone is known probably from the Lower Malm (Oxfordian). In the Kimmeridgian to the Lower Tithonian and probably already in the Oxfordian deposited the Klentnice beds. They represent sediments of not too deep sea with conditions similar to that of the Black sea. Original extension of the Klentnice beds (K. Jüttner, 1933) as it was suggested formerly did not correspond with true extension and therefore it was recently studied by A. Matějka and Z. Stráník (1961–1962). From nine types of K. Jüttner (1933) belong to the Klentnice beds only four ones and beds found by recent investigations. Recently revised Klentnice beds are made up of

Table 2.

ELEVATED ZONE OF PAVLOVSKÉ KOPE - ŠTRAMBERK				GEOSYNCLINAL CETECHOVICE ZONE		GEANTICLINAL CZORSTYN ZONE		GEOSYNCLINAL PIENIDY ZONE					
PAVLOVSKÉ KOPE REGION		ŠTRAMBERK REGION		VICE ZONE		CZORSTYN ZONE		KYSUCA-BRANISKO SERIES		PIENIDY TRANSITIONAL DEVELOPMENTS (SERIES)		HALIGOVCE - KLAPE SERIES	
MARGINAL PART		CENTRAL PART				PARTICULAR SERIES		PARTICULAR SERIES		TRANSITIONAL DEVELOPMENTS (SERIES)		TRANSITIONAL DEVELOPMENTS (SERIES)	
ERNSBRÜNN LIMESTONE (A. BOUÉ 1830)		STRAMBERK LIMESTONES (to 500 m)		WHITE - GREY TO GREY AND GREENISH - GREY		WHITE - GREY LIMESTONES (WNEUMAYR 1871)		WHITE - GREY LIMESTONES		CHERTY MARLY LIMESTONES ("BIANCONE")		CHERTY MARLY LIMESTONES	
(100 - 120 m)		LOWER TEŠÍN BEDS (300 - 400 m)		NODULAR		BIRKENMAYER (1957)		LIMESTONES		ABUNDANT CALPIONELLAS (GLOBOCHAETE NANNOCONUS, (RADIOLARIA)		INTENSIVELY CHERTY LIMESTONES	
KLENTNICE BEDS (K. JÜTTNER 1933)		HIATUS		CALPIONELLA LIMESTONE		ROGOŽNIK BEDS KZITTEL (1870)		10 m		150 m		<100 m	
(60 m)		HIATUS		LIMESTONE		IRANELLICERAS LITHOGRAPHICUM		10 m		100 m		30 m	
		HIATUS				RED AND WHITE CALPIONELLA LIMESTONES SOMETIMES NODULAR LIMESTONE		WHITE BEDDED CALPIONELLA LIMESTONES		CALPIONELLA LIMESTONES		SACCOCOMA LIMESTONES	
						SACCOCOMA LIMESTONES		5 m		SACCOCOMA LIMESTONES		SACCOCOMA LIMESTONES	
						CALPIONELLA		CALPIONELLA		CALPIONELLA		CALPIONELLA	
						CALPIONELLA		CALPIONELLA		CALPIONELLA		CALPIONELLA	
						CALPIONELLA		CALPIONELLA		CALPIONELLA		CALPIONELLA	
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grey to black-grey, locally light-grey to light-yellow sandy calcareous claystones with mica which are alternated with grey to light-grey, sometimes reddish sandy or clayey limestones. In lower parts of the beds predominate claystones with thin intercalations of limestones, only rarely to 120 cm thick. In upper parts of the beds increases an amount of limestones. Intercalations of limestones reach the thickness of 7 m. In the uppermost parts of the limestones predominate and they are frequently oolitic, crinoidal or cherty.

By the way of the sedimentary-petrographic analysis M. Eliáš (1961) distinguished in the Klentnice beds polydetrital limestones (fine-grained, fine-psefitic) and fine-grained to pelitomorph, sometimes organogenic-muddy. Calcareous claystones are composed of illite minerals of the montmorillonite group, calcite and organic substance.

These beds carry rich, but stratigraphically indifferent fauna. K. Matzka (1934) found here and described *Apiocrinus mespiliformis* Schloth., *Apiocrinus muelleri* Schloth., *Hemicidaris conoideus* Quenst., *Hemicidaris mitratus* Quenst., *Tholicecrinus flexuosus* Gldf., *Terebratula bisuffarcinata* Schloth., *Terebratula insigbalis* Schübl., *Terebratula saxonica* Bruder var. *ovalis*, *Rhynchonella normalis* Suess, *Waldheimia magadiformis* Zeuschner, var. *pentagonalis*, *Pecten moravicus* Remeš, *Pecten* aff. *vimineus* Sow., *Pecten subtextorius* Münster., *Lima* (*Ctenoides*) *ctenoides* Boehm. *Protetragonites quadrisulcatum* (d'Orb.), *Pseudovirgatites scruposus* (Oppel), *Opelia* sp. V. Pokorný (personal communication) found in these beds *Ostracoda*. Stratigraphical position of the Klentnice beds was established on the basis of comparatively poor Ammonites fauna found near Nieder Fellabrunn in Austria. L. F. Spath (1933) regarded this macrofauna as of Upper Kimmeridgian age, M. Glaessner (1937) as of Lower Tithonian age. J. W. Arkell (1956) compares this macrofauna with the Lower Tithonian fauna of southern Germany [F. Bachmayer (1957)] and D. Andrusov (1959) regards the Klentnice beds as of the Lower to Middle Tithonian age.

By new micropaleontological investigations in these beds was found association of similar species as that found and described by V. Pokorný (1959). E. Hanzlíková (in press) quotes these species: *Haplophragmoides aequalis* (Roemer), *Ammobaculites* ex gr. *suprajurensis* (Schwager), *Gaudryina heersumensis* Litze, *Reophax horridus* (Schwager), numerous arenaceous Foraminifera, *Lenticulina brückmani* Mjatljuk, *Lenticulina münsteri* (Roemer), *Marginulinopsis costata* (Batsch), *Planularia filosa* (Terquem), *Vaginulina* ex gr. *zaglobensis* Bielecka-Pozaryski, *Nodosaria striatojurensis* Klähn, *Marssonella* cf. *oxycona* (Reuss), *Tristix acutangulatus* (Reuss), *Trocholina solecensis* Bielecka-Pozaryski, *Epistomina stelicostata* Bielecka-Pozaryski. E. Hanzlíková regards this microfauna as of the Kimmeridgian (or Oxfordian to Kimmeridgian) age. However, we suppose here also the Lower Tithonian.

The thickness of the Klentnice beds is more than 100 m.

In the Lower Tithonian the epicontinental sedimentary district was emerged and the geosynclinal one deepened. In the district of Pavlovské kopce was shallowing and regression of the sea (the uppermost Klentnice beds). Thus developed favourable conditions for the growth of reefs (lower portions of the Ernstbrunn limestones) — regressive reefs in the sense of T. A. Link (1950).

The Ernstbrunn limestones were distinguished by A. Boué (1830). They

Table 3.

Geanticlinal High-Tatric Zone						Geosynclinal Veporidy and Gemeridy Zone		
						Križná Series	Higher Subatric Series	Gemeridy Series
	„Exotic“ Series	Manín and Tomanová Series H. T.	Overthrust High-Tatric Series	Mantle Series				
Tithonian	Upper	Birkenmajer (1960) ?  pink  oolithic  limestones	light-grey  cherty  Calpionella  limestones	white and grey      massive limestones	grey yellow bedded massive marly limestones   in other places light-grey organogenous limestones in other places	marly limestones and marls  Proletragonites quadrisulcatus (Nizke Tatry)  massive bedded  Calpionella	?	cherty limestones with Aptychi
	Middle							
	Lower	with Globochaete alpina Lomb. ?			grey cherty limestones	limestones		?

grade upwards from the Klentnice beds. They represent predominantly light-grey and thick-bedded organogenously-detrital fine- to coarse-grained and yellowish-grey, green breccia-like limestones, less frequently massive and pulverized. In the lower portions occur thin intercalations and smudges of dark-grey sandy calcareous claystones and portions of light-grey to bluish-grey limestones, locally with honied cherts, further with grey sandy-clayey and oolitic limestones of the Klentnice type. Frequently we may find here also bioherms (light-grey to bluish limestones with corals, Stromatoporoidea etc.). The breccia-like limestones occur in the form of irregular interbeds in organo-detrital limestones (predominantly in the lowermost portions). They are composed of fragments to blocks of imperfectly worked organo-detrital limestones closed in the basal sandy-clayey mass, sometimes with glauconite. In the uppermost portions the organodetrital limestones are slightly reddish. In the lower parts they become brownish. Locally we may see the leaks (on the stratification planes and faults) of yellowish-green marls and dolomitized portions (J. Matějka, 1926).

From the sedimentary-petrographic point the Ernstbrunn limestones are composed of the detrital limestones, mainly of coarse-psammitic to fine-psefitic structure, fine-grained or lump, pseudoolithic and coarse-psefitic to breccia-like (M. Eliáš in A. Matějka, Z. Stráník, 1962).

The macrofauna of the Ernstbrunn limestones was studied by K. Matzka (1934). Predominate Echinodermata (genera *Cidaris* Leske, *Rhabdocidaris* Desor, *Apiocrinus* Müller), *Brachiopoda* (*Rhynchonella astieriana* d'Orb., *Waldheimia* King, *Terebratula besikidiensis* Zauschn., *Terebratula insignis* Schlübl., *Terebratula tychoaviensis* Suess), Lamellibranchiata (mainly genera *Pecten* Lamk., *Lima* Brug., *Ostrea* Lamk., *Diceras* Lamk.), and *Gastropoda* (genera *Natica*, *Pleurotomaria*).

From bluish-grey limestones on Turol J. Pia (1922) quotes *Girvanella* sp. (*Girvanella minuta* — D. Andrusov, 1959) and *Solenopora* sp. In green cement of the breccia-like limestones and in green marls which fill up cracks in the limestones and fissures was found by E. Hanzlíková microfauna of the Štramberské biofacies with *Trocholina* sp.

Stratigraphically the Ernstbrunn limestones belong to the Middle-Upper Tithonian. Thickness of these limestones is 100–120 m.

The Ernstbrunn limestones occur above the Klentnice beds. Only their lowermost portions composed of the breccia-like limestones are laterally connected with the uppermost Klentnice beds. They may be regarded as isopic facies of the Štramberské limestones (F. Trauth, 1948; D. Andrusov, 1959). J. W. Arkell (1956) regards the fauna as a mixture of the Kelheim and Štramberské faunas. With the Ernstbrunn limestones ends the Jurassic sedimentary cycle in the zone of Pavlovské kopce.

The Štramberské zone (recently studied by V. Houša) occupies on our territory the northern part of the Pavlovské kopce—Štramberské zone approximately in space from Hranice to Ostrava. At the south it was probably separated from the Pavlovské kopce zone by peninsula which extended from the dry land of the Bohemian massif to the south-east toward to Carpathian district (Z. Roth, 1959). At the south probably ended near the Bachovice depression (M. Książkiewicz, 1956). The northern side then was represented by the Debece zone similar to that of Štramberské.



Suffusion of the Štramberg zone by a sea became as far as in the ? Middle-Upper Tithonian. During this time developed the Štramberg limestones which occur now in some tectonic fragments in the Silesian unit in the vicinity of Štramberg, single fragments near Skalička, Nĕmetice and Černotín and on the other hand in form of fragments, pebbles to blocks, frequent in the Cretaceous and Tertiary suites of the series: subsilesian, silesian and Magura (Z. Roth and coll., 1962 a, b). The Štramberg limestone is predominantly light-grey to white-grey, fine- to medium-grained, organodetrital limestone, sometimes organodetrital-muddy or coarse-grained without distinct stratification which may be suggested only on the basis of the alternation of beds of detritus (of various grains). Occasionally were found also organogenous limestones. The petrographic character of main types of the Štramberg limestones was described by M. Eliáš (1962).

From rich fauna found in the Štramberg limestones (the last detail list was described by F. Blaschke, 1911 — about 600 species) very important for stratigraphy are Ammonites: *Virgatosphinctes transitorius* (Oppel), *Sublithoceras senex* (Oppel), *Micracanthoceras micracanthum* (Oppel), *Aulacosphinctes fraudator* (Zittel), *Aulacosphinctes eudichotomus* (Zittel), *Dalmaticeras progenitor* (Oppel), *Proniceras pronicum* (Oppel), *Berriasella oppeli* (Kilian), *Berriasella richteri* (Oppel), *Pseudoargenticeras abscissum* (Oppel) and other, which may serve as evidence of the Upper Tithonian age. The Štramberg limestone probably corresponds to almost all the Upper Tithonian and the Uppermost Tithonian evidently is missing (V. Houša, 1961 a, b). It is due to lacking of some species, characteristic in other areas (with continued sedimentation) for the Uppermost Tithonian, directly under the boundary Jurassic-Cretaceous such as *Berriasella chaperi* (Pictet), *Dalmaticeras djanelidzei* Mazenot, *Neocomites suprajurensis* (Mazenot) and other.

From the Štramberg limestones A. K. Zittel (1868), F. Blaschke (1911) quote also such species of Ammonites which give an evidence for an earlier age of the rocks from which they descend (Middle Tithonian). On some localities in the exotic blocks in the lowermost Lower Cretaceous suites were found *Pseudovirgatites seorsus* (Oppel) and *Pseudovirgatites scruposus* (Oppel). The last species was found also in Štramberg together with „antique“ forms *Virgatimoceras kittli* (Blaschke), *Virgatimoceras steindachneri* (Blaschke), *Simoceras remesi* Blaschke, *Aspidoceras rogoznikense* Zeuschner etc. The accurate locality is not known now. Therefore it is out of the question that also in the Štramberg zone deposited already the beds of the Middle Tithonian (only its upper parts). It must be pointed out that the index Middle Tithonian forms [*Protancyloceras* Spath, *Pseudolissoceras* Spath, *Semiformiceras semiforme* (Oppel) etc.] were not found in the Štramberg limestones and it is not impossible that the mentioned antique species may represent the lowermost Upper Tithonian.

The boundary between the Štramberg limestones and the Cretaceous is sharp. Just before the end of the Tithonian there was a regression of the sea in this region. The lowermost Cretaceous (Berrias and Valanginian) lies on the Štramberg limestone transgressively (V. Houša, 1961 b).

The Štramberg limestone is in main part composed of organic detritus of various grains. By V. Houša (1961 b) the Štramberg limestone represents

remains of detrital material descending from bioherms occurring near the coast of the Tithonian sea. H. Eliášová-Fraňková (1962) and M. Eliáš (1962) suppose that the Štramberské limestones represent true Tithonian reef. The thickness is to 500 m (Z. Roth and coll., 1962 b).

The further division of the Štramberské limestone is not possible in recent time. Recent investigations among others are directed with a view to the stratigraphical superposition in the single tectonic fragments which is a main facility for the future solution.

The Koprivnice limestones (Nesseldorfer Kalkstein) up to present are regarded as Tithonian, as facies of the Štramberské limestones are of the Lower Cretaceous age (Berrias) (V. Houša, 1961 b). This opinion up to present is not generally accepted. M. Eliáš (1962) supposes that the Koprivnice limestones are the local equivalent of the lower part of the Štramberské limestones. But the fauna of the Koprivnice limestones does not give an evidence of it (V. Houša, 1961 b).

The lower Těšín beds probably are of the Tithonian age. They deposited in deeper, more distant from the coastal parts of the Štramberské sedimentary district, parts. During the regression between Jurassic and Cretaceous in the marginal parts of the Štramberské district occurred the emersion (end of sedimentation in the Štramberské limestones), in the central part then in consequence of it the change of the sedimentation which manifested in appearance of the limestone beds associated with light-grey calcareous claystones which belong already to the Těšín limestones (Berrias).

## 2. Geosynclinal zone of Cetechovice (Elaborated by V. Houša)

This zone extended south-east of the geanticlinal zone of Pavlovské kopce—Štramberské. The sea penetrated here already in the Lias (Lukoveček) and kept a shallow-water character still in the Dogger. During the Malm this particular geosyncline was deepened with maximum in the Tithonian. Deposited here the pelagic sediments, heteropic in connection with "reef" limestones of Pavlovské kopce—Štramberské zone (D. Andrusov, 1959). The pelagic sedimentation continues within this region without an interruption to the Lower Cretaceous.

The Tithonian sediments of Cetechovice zone were found in fragments in front of the Magura nappe and in the pebbles and blocks of conglomerate of the Solán beds in the frontal part of the Magura flysch. Their occurrences are known near Kurovice, Cetechovice, Konečná, Holý kopec, Koryčany etc.

Near Koryčany occur the Tithonian limestones in the tectonic fragment near the frontal part of the Magura nappe. Firstly they were described by E. F. Glocker (1842), then by K. Zapletal (1932); D. Andrusov (1933, 1959); E. Menčík, V. Pesl (1960) and A. Matějka (in T. Buday, 1960).

The Tithonian here is developed in form of light-grey to grey fine-grained and massive, greenish-grey muddy limestones (beds of 10–50 cm thickness), which are alternated with to 1 m thick beds of marls of the same colours. Locally occur here thin interlayers of organodetrital limestones with fragments of Aptichia and Radiolaria. Besides Aptichia [*Punctaptychus punctatus* (V o l t z), *Lamellaptychus beyrichi* (O p p e l), *Lamellaptychus lamellosus* (P a r k.)], Radiolaria (genera *Sphaerocyclonema*, *Conosphaera*, *Cenellipsis*, *Ellipsozaphus*, *Lithapum*, *Rhopalastrum*, *Staurosphaera*, *Stichocapsa*) in the limestones were found



numerous *Calpionella alpina* Lorenz (D. Andrusov, 1933). The mentioned fauna shows the Tithonian age. On the basis of Aptichi it is not out of the question also the Kimmeridgian age (compare D. Andrusov, 1959). The thickness of the beds is about 100 m.

Higher the Tithonian beds of the Kurovice fragment grade upwards into the green and grey variably sandy light-yellowish, brown marls. In the upper beds they enclose numerous interbeds (2–10 cm thick) of fine-grained calcareous clayey sandstones (A. Matějka in T. Buday, 1960). D. Andrusov (1959) quotes from these beds Lower Neocomian Aptichi and E. Hanzlíková (in T. Buday, 1960) microfaunistic associations of the Valanginian to Aptian.

Cetechovice. The Jurassic occurrences are south and south-east of Cetechovice in three fragments. Here is also the Kelloway?, Oxfordian to Berriasian-Valanginian. They were described by E. F. Glocker (1842) and by many other authors. Recently they were studied by F. Chmelík (1957) who quotes also all older literature.

To the Tithonian belong light-grey *Calpionella* limestones which occur in the northern occurrences of the Cetechovice-type klippens (locality III of F. Chmelík). V. Pokorný (in F. Chmelík, 1957) found here *Calpionella alpina* Lorenz and *Calpionella elliptica* Cadisch. By V. Uhlig (1903) and F. Chmelík (1957) the Tithonian limestones on this locality were found in fragments (8 × 4 m) in conglomerates. Recent investigations do not exclude a possibility that this fragment represents a block in the conglomerates of the Solán beds (F. Chmelík, personal communication).

Stratigraphically older beds (Kelloway? — Oxfordian — Argovian, Kimmeridgian) with numerous Ammonites (*Cardioceras cordatum* zone, *Gregoryceras transversarium* zone) were found in the eastern occurrence of Cetechovice (J. Neumann, 1907). Stratigraphically higher beds than Tithonian (Berriasian-Valanginian) with *Tintinnopsella carpathica* (Murgeanu—Filipescu) and *Calpionella* sp. (V. Pokorný in F. Chmelík, 1957) appear in the central occurrence of the Cetechovice-type klippens (locality II of F. Chmelík).

Near Vigantice were found the Tithonian limestones in the tectonic fragment in the Krosno beds of the Silesian unit south-east of the village near the settlement Na Vápenkách before the front of the Magura klippen (B. Zahálka, 1927; E. Oppl, 1930; V. Šusta, 1942; A. Matějka; Z. Roth, 1947).

They are represented by light-grey massive, fine-grained irregularly bedded limestones. J. Koutek (in B. Zahálka, 1927) found here numerous specimens of *Calpionella alpina* Lorenz, calcified Radiolaria and silicified parts (concretions). E. Oppl quotes from these beds *Lamellaptychus beyrichi* (Oppl), *Punctaptychus punctatus* (Voltz), Belemnites and spines of echini. Very abundant are recrystallized spiculae of sponges and Foraminifera (M. Eliáš in Z. Roth, 1962).

In the frontal part of the Magura klippen occur the Tithonian limestones of the Cetechovice zone mainly in the form of pebbles and blocks in the conglomerates of the Solán beds (Holý kopec near Koryčany) and perhaps in the form of small klippens (Konečná).

Near Konečná (867,5 m) south of the road between Bílá and Turzovka A. Matějka and Z. Roth (1949) described the klippens of white massive limestone and brown-grey fine-grained pseudoolithic limestone (Z. Roth, 1962).

On Holý kopec near Koryčany the Tithonian light-grey slightly yellowish massive limestones occur in the form of pebbles and blocks in unsorted coarse-grained to block-like conglomerates of the Soláň beds. D. Andrusov (1932, 1959) describes here *Calpionella elliptica* Cadisch, Radiolaria, spiculae and sponges, Foraminifera and remains of Mollusca.

The pebbles of the Tithonian limestones are extended in whole the frontal area of the Magura nappe (mainly in Chříby). In direction toward the inner parts of the Magura flysch we may observe the distinct decreasing of these pebbles (A. Matějka in T. Buday, 1960).

Extension of the pelagic Tithonian limestones in the beds of various sedimentary units shows that an extent of the geosynclinal zone of Cetechovice was not the same as in the later zone in the Upper Cretaceous and Paleogene.

### 3. Geanticlinal Czorsztyn zone (Elaborated by E. Scheibner)

In the region of the particular Pienidy geosyncline in which deposited suites building the recent klippen belt we may distinguish from north to south the main series as follows: Czorsztyn geanticlinal, Pieniny deep-water, Haligovka-Klape, geanticlinal and between these series of the transitional developments and series: Pruské, Podbiel, Czertezik, Niedzica developments and Kysuca, Branisko series (E. Scheibner, 1961).

The Tithonian of the Czorsztyn series from the biostratigraphical standpoint is very completely characterized.

The Lower Tithonian (zone with *Taramelliceras lithographicum*) is represented by the subpelitomorphic red and white nodular limestones of the Czorsztyn type (K. Birkenmajer, 1957). Up to present from these limestones is known only *Calpionella alpina* Lorenz (Tithonian), also *Globochaete alpina* Lombard. Locally instead of *Calpionella* limestone occur pink and white *Globochaete* limestones. These limestones represent in fact the uppermost part of the Czorsztyn limestones which are on a whole of the Kalloway (Bathonian) to Kimmeridgian age, characterized by rich Ammonites fauna. The thickness is 8–10 m.

The Middle Tithonian (zone with *Semiformiceras semiforme*) is represented by the known Rogoźnik beds with typical and rich Cephalopoda fauna, described mainly by K. Zittel (1870). Lithologically they are composed of organogenous Brachiopoda and Ammonites breccia, crinoidal limestones, massive light pink limestones with *Calpionellas* and *Globochaete*. The thickness is about 10 m. In these beds was found fauna as follows: *Globochaete alpina* Lombard, *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadisch, *Lamellaptychus beyrichi* (Oppel), *Phylloceras serum* Oppel, *Caliphyllloceras kochi* (Oppel), *Ptychophylloceras ptychoicum* (Quenst.), *Holcophylloceras silesiacum* (Zitt.), *Lytoceras montanum* (Oppel), *Protetragonites quadrisulcatum* (d'Orb.), *Haploceras rasile* Oppel, *Haploceras elimatum* Oppel, *Semiformiceras semiforme* (Oppel), *Aspidoceras rogoznikense* (Zeuschner), *Simoceras valanense* (Oppel), *Simocosmoceras catulloi* (Zittel), *Simocosmoceras adversum* (Oppel), *Simocosmoceras simum* (Oppel), *Peripshinctes pseudocolubrinus* Kilian, *Lithacoceras geron* (Zitt.), Sub-

*planites contiguus* (C a t.), *Micracanthoceras micracanthum* (O p p e l), *Bochia-nites guembeli*.

K. Zittel (1870) from the Rogoznik beds quotes *Taramelliceras lithograph-icum* (O p p e l) which W. J. Arkell (1956) is not regarded as identical with holotype. Now, on the basis of our knowledge of the facial variety of the Czorsztyn series we may suppose that locally the Rogoznik beds occur already in the lowermost zone of the Tithonian and from these portions descends Zittel's found of *Taramelliceras lithographicum* (O p p e l). By this way we may explain also an appearance of some younger elements in fauna. The pre-dominant part of the Rogoznik beds represents the zone with *Semiformiceras semiforme*. From this follows that by K. Zittel (1870) described fauna is probably mixed and represents mainly the II. zone of the Tithonian with elements of the I. and III. zones.

The Upper Tithonian. In the klippen belt in Eastern Slovakia near Kyjov and Paloča M. Neumayr (1871) found and described from white-grey veiny limestones these species: *Protetragonites quadrisulcatum* (d' O r b.), *Phylloceras serum* (O p p e l), *Ptychophylloceras ptychoicum* (Q u e n s t.), *Holcophylloceras silesiacum* (O p p e l), *Haploceras elimatum* (O p p e l), *Substreblites zonarius* (O p p e l), *Virgatosphinctes transitorius*, *Micracanthoceras micracanthus* (O p p e l). This association is very similar to that of the Štramberk limestones, i. e. it is of the Upper Tithonian age. By K. Birkenmayer (1957) in the Pieniny klippen belt above the Rogoznik beds lay red, variegated crinoidal limestones, sometimes nodular with *Globochaete alpina* L o m b., *Tintinnopsella carpathica* (M u r g. et F i l i p e s c u) (Upper Tithonian-Berriasian), further white, greenish, pink, organodetrital limestones with scarce Crinoids, with *Globochaete alpina* L o m b. and *Calpionella elliptica* C a d i s c h.

Special development occurs in Považie, represented by grey massive or fine-grained limestones. Up to present was found only *Lima paradoxa* Zitt. This development resembles the Štramberk one in the character of limestones, however, without determinable fossils. Stratigraphically it represents the Neocomian as K. Borza (1960) found here *Calpionellites darderi* (C o l o m).

At the end of the Tithonian, respectively Neocomian, the sedimentation in the Czorsztyn series at many places was interrupted. K. Birkenmajer (1953) supposes only submarine erosion. D. Andrusov, E. Scheibner, V. Scheibnerová, J. Zelman (1959) found evidences of considerable erosion. On the eroded surface of the Malm limestones (grey, pink, massive limestones with remains of planctonic Crinoids — *Saccocoma* — which are typical for the Kimmeridgian, Lower Tithonian) transgresses the Albian [variegated marly limestone, marly slates with *Globigerinas* and *Ticinella roberti* (G a n d.)]. This occurrence apparently represents a manifestation of Youngcimmerian movements which took place with various intensity and in various time in the geanticlinal sedimentary district of the Czorsztyn series.

#### 4. Pienidy geosynclinal zone (Elaborated by E. Scheibner)

The Tithonian of the Pieniny series s. s. is made up of thick suite of cherty marly massive light-grey limestones of the "biancone" type (Hornsteinkalk, M. Neumayr, 1871). Microscopically they represent pelitomorph limestones

with Radiolaria and Calpionellas. In the Tithonian occurs *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadisch. In the Uppermost Tithonian to Berriasian appears *Tintinnopsella carpathica* (Murg. et Filip.) and higher the Neocomian association of Calpionellas. In fine-grained variety of the limestones are abundant Coccolites, representatives of genus *Nannoconus* K a m p t n e r. Lacking are whatever traces of the accumulation of detrital material (D. Andrusov, E. Scheibner, 1960). Locally in these limestones occur numerous Aptichi [*Lamellaptychus beyrichi* (O p p e l)], in upper portions was found *Lamellaptychus angulocostatus* (Peters) which may serve as an evidence of grading upwards into the Neocomian.

Between the (4) Czorsztyn geanticlinal and (5) Pieniny geosynclinal series deposited suites in which on the basis of differences in sedimentation were distinguished numerous transitional developments and series (see below).

In the transitional developments the Tithonian is made up of the upper nodular limestones. In the Pruské development red nodular limestones grade upwards into yellowish, massive, pelitomorph limestones with *Calpionella alpina* Lorenz and *Calpionella elliptica* Cadisch. From the nodular limestones descends *Protetragonites quadriculatum* (d'Orb.).

By K. Birkenmajer (1960) in the transitional developments (Czertezik and Niedzica) the Lower Tithonian is composed of Calpionella limestones of 2–4 m thickness. Sedimentation in the Middle and Upper Tithonian was interrupted. In some parts of the Niedzica development whole the Tithonian is built by the upper nodular limestones.

The Tithonian-Berriasian of the Kysuca, Branisko series is made up of a suite of pink limestones of the "biancone" type. They represent massive, sublithographic bedded, sometimes thickbedded limestones with abundant stylolites and scarce dark cherts. Between layers of the limestones occur single interbeds of marly slates of grey colour. Important are microorganisms in the lower part of the suite: *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadisch and higher appears *Tintinnopsella carpathica* (Murg. et Filip.). Very abundant is *Globochaete alpina* Lomb. and *Nannoconus* K a m p t n e r. From macrofossils were found: *Lamellaptychus beyrichi* (O p p e l), *Lamellaptychus lamellosus* (V o l t z), *Ptychophylloceras ptychoicum* (Q u e n s t.), *Rhynchonella spoliata* (S u e s s). This suite grades upwards into the Neocomian (D. Andrusov, E. Scheibner, 1960).

In the southernmost part of the Pieniny particular geosyncline were deposited suites which build the Haligovka-Klape series, which is of shallow-water character. The Tithonian of the Haligovka series is composed of a suite of cherty limestones with similar microfauna as in other klippen series.

It is obvious that there is a transitional series between the Pienidy and Haligovka-Klape series. It is possible that it shows affinities to the Kysuca and Branisko series. It is further possible that some of recently known klippen built by the Kysuca series are of this type. Probably also the Podbiel development deposited in this region. The Tithonian-Neocomian in this region is identical with the Tithonian-Neocomian of the Kysuca series as well as it is in the Podbiel development.

### 5. *Tatrid geanticlinal zone* (Elaborated by E. Scheibner)

South of the particular Pieniny geosyncline laid the Tatrid sedimentary district which was in general of the shallow-water character. Deposited here suites building the so called mantle series of the core mountains of Central West Carpathians.

Somewhere between the Pieniny and Tatrid regions extended the "exotic" series (K. Birkenmayer, 1960) from which descends the exotic material of the Upper Cretaceous exotic conglomerates.

The Manín series which is a tectonic member of the klippen belt has the Tithonian composed of marly limestones of grey colour without cherts and with *Calpionella alpina* Lorenz (M. Mišík, 1957).

In the Hightatric series of High Tatra the Tithonian is composed of white and light-grey limestones in the upper parts of which was found *Calpionella alpina* Lorenz.

In the Šiprún series the Tithonian is made up of a thick suite of bedded cherty limestones of "biancone" type with *Calpionella alpina* Lorenz.

In other Tatric series we may find various variants of the mentioned two types of rocks.

### 6. *Geosynclinal zone of Veporids and Gemerids* (Elaborated by E. Scheibner)

South of the Tatrid district extended the sedimentary district of the Veporids and Gemerids which on a whole was of a deep-water character. Deposited here series, later folded in form of nappes and overthrust the Tatrid zone (see D. Andrusov, 1959; D. Andrusov, J. Bystrický, 1959).

In the Križná series (lowermost tectonic unit) the Tithonian is made up of a suite of bedded marly limestones with *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadisch. It represents a monotonous suite grading upwards into the Neocomian. From Small Tatra is known *Proteragonites quadrisulcatus* (Quenst.). From microorganisms occur here in abundance *Calpionella alpina* Lorenz and *Calpionella elliptica* Cadisch, Radiolaria and representatives of the genus *Nannoconus* Kämtner.

In the Choč series (higher tectonic unit) the Tithonian is composed of bedded marly limestones with interbeds of slates which grade upwards into the Neocomian as well as in the Križná unit. The microfauna is similar to that of the last mentioned series.

In the Gemerids series of probably Upper Jurassic age are cherty limestones with Aptichi and Belemnites.

### Conclusions

On a whole in Central Carpathians we may distinguish two developments of the Tithonian: deep-water, respectively pelagic, deposited in the particular geosynclines, made up usually of monotonous suite of bedded massive pelito-morph limestones, frequently of "biancone" type with cherts which grade upwards into the Neocomian. The second development is more shallow-water,



geanticlinal, composed of various types of organogenous limestones. At the margin of the platform which represented the foreland of the Carpathian geosyncline grew the coral reefs and by the destruction of these reefs developed the Štramberk-type limestones, respectively other types of the organogenous limestones.

The first development has only poor and scarce fossils and usually it is lithologically undistinguishable from the Neocomian. For the stratigraphy very important are *Calpionella alpina* Lorenz, *Calpionella elliptica* Cadisch and in the Upper Tithonian together with two last forms *Tintinnopsella carpathica* (Murg. et Filip.). Very rich and abundant is *Globochaete alpina* Lomb., representatives of the genera *Stomiosphaera* Wanner and *Nannoconus* Kampfner. The representatives of the last genus are of the rock-building importance. Abundant are also Radiolaria. The rests of the last organisms composed of  $\text{SiO}_2$  represent a source of  $\text{SiO}_2$  for cherts in the limestones. An attempt to use Aptychi for establishing of accurate stratigraphy (S. M. Gosiański, 1959) was not yet realized. Scarcely occur Ammonites on the basis of which we may establish an approximate stratigraphy.

Geanticlinal developments are rich in fossils and therefore they were distinguished into zones in the Tithonian. Facial variety is a reason of impossibility to applicate observations from the type localities without detailed study in field.

The most rich macrofauna occurs in the Rogožnik breccias which predominantly belong to the middle zone of the Tithonian with *Semiformiceras semiforme*. Due to the facial variety these types of rocks occur locally more earlier in the Ist zone, locally higher in IIIrd zone which up to present was a matter of discrepancies and discussion as K. Zittel (1870) quoted forms from all known occurrences of the Rogožnik breccias together.

Translated by V. Scheibnerová.

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Review by D. Andrusov.